

THE USE OF PERFORMANCE INCENTIVES IN DOD CONTRACTING

Gregory G. Hildebrandt

Performance incentives have a long and interesting history in the Department of Defense (DoD). As a result of policy guidance, numerous contracts written during the 1960s and 1970s based profit, in part, on objectively measured performance characteristics. Such contracts may have renewed policy relevance today because of both the change from detailed design-to-performance specifications and the implementation of Cost as an Independent Variable (CAIV). During a time of rapid technological change, performance incentives may also support the decentralized execution of a centralized planning process. In this analysis particular attention is paid to the DoD cost-effectiveness model developed during the 1960s. Using the policy prescription of this model, we examine the empirical relationship between the performance achieved by contractors and such variables as the cost sharing ratio, target cost, and target profit. Recently economists have extended this model by emphasizing the distinction between accounting profit and economic profit when contractor effort is unobservable. We argue that the government is likely to know a great deal about the contractor's effort and that contracts combining performance incentives with subjectively determined award fees may have very desirable properties. The F/A-18E/F contract is an important example of this type of incentive arrangement.

The breakup of the Soviet Union demonstrated that traditional centralized planning was not able to respond to local demand and supply conditions. There was a mismatch between economic institutions and the technological conditions of production. The lack of an adequate incentive system in Soviet central planning made it ill-equipped to deal with the variegated information requirements of a modern industrial society. The

problems faced during the acquisition process are similar. The information requirements to directly plan performance outcomes are daunting. This is particularly true as the United States continues to lead the microprocessor-based revolution in military affairs, in which sensors, communications, and precision weapons are changing the speed and effectiveness of military operations. Clearly, to manage development during a period of radical

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change with localized information, we must have acquisition policies that permit centralized planning with decentralized execution.

Weapon system development, particularly engineering and manufacturing development (EMD), is one of the most demanding "management of change" environments. In this environment, the traditional issues of central planning, particularly those associated with the relationship between technology, information, and economic institutions, are faced. To what extent should the government micromanage the activities of contractors by direct involvement in detailed decision making during engineering development? Are there incentive structures that can guide contractors' decision making toward the development of weapons systems that achieve the objectives of the government and exploit the contractor's knowledge of the detailed cost versus performance tradeoffs?

In this analysis, we discuss why performance incentives, that is, a profit function based on the performance level achieved by the contractor, may help effectuate this requirement. Performance incentives embody the government's values with respect to enhancements in the value of performance—the government's primary area of expertise during the acquisition process. They also guide contractors to achieve these objectives by permitting contractors to make detailed tradeoff

decisions that are cost effective—the contractor's primary area of expertise during development. Thus, performance incentives may help effectuate management of radical change during acquisition.

Recently, a number of economists have suggested that the efficiency of the defense procurement process could be enhanced by making use of new developments from economic theory.¹ A theme running through much of this literature is that the management of a resource allocation process must take account of the information asymmetries that exist at different organizational levels. These asymmetries are present in the contractual relationship that exists between the government and its contractors, and contractual instruments must be designed that properly deal with the distribution of information.

The government has explicitly dealt with this distribution of information issue during the acquisition process when the contractor receives a profit that varies with the objectively measurable performance characteristics of the equipment. These rewards for performance functions have been used in incentive contracts in which the defense contractor shares some proportion of the contract costs with the government. When a contract includes both cost and performance incentives, it is called a multiple incentive contract.

As is seen below, the established policy for the use of performance incentives is derived a particular view of how a

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performance change can be efficiently managed, given the structure of information. In this environment, the government is presumed to know the value of performance enhancement and the contractor knows the detailed tradeoff opportunities between cost and performance that arise during the contract.

Traditional incentive contracts with performance incentives can be contrasted with contracts in which fee is partly based on a subjective assessment of contractor behavior and performance. A contract containing this type of fee is called a cost plus award fee (CPAF) contract.

Interestingly, the Navy has recently employed an EMD contract for the F/A-18E/F that includes cost and performance incentives and also contains an award fee provision. The contractor shares a portion of the development costs in a conventional cost-plus-incentive-fee (CPIF) cost incentive. There is also a schedule incentive, in which certain funds are withheld until first flight is achieved. In addition, the contractor can receive a fee based on both objectively and subjectively determined performance. Fifty percent of this fee is based on technical performance, of which 70 percent is based on demonstrated measurable performance and 30 percent based on a subjective government assessment of technical performance. The remaining 50 percent of the award fee is based on a subjective government assessment of contractor management and logistics. The F/A-18E/F contract, therefore, combines features of a CPIF multiple incentive contract and a CPAF contract. The contract, therefore, can be described as CPIF/AF contract.²

As will be seen, this type of contract aids the management of change in a somewhat different dimension of the

informational environment. When award fees are used, it is assumed that the government can properly assess certain aspects of contractor behavior, by the completion of the contract, that may be impossible to define at the time the contract is awarded.

There are two recent policy changes that bear on the use of performance incentives. One is the emphasis being given performance specifications rather than detailed design specifications; the second is the recent implementation of CAIV.

"Performance incentives only are practicable if there are opportunities for tradeoffs to be made during the contract."

The use of performance specifications and performance incentives are strongly interrelated. Performance incentives are practicable only if there are opportunities for tradeoffs to be made during the contract. Performance specifications combined with an Operational Requirements Document (ORD) that identifies both "threshold" and "objective" performance levels increases the number of tradeoffs that can be made. In contrast, detail design specifications may preclude many tradeoffs possibilities.³

CAIV expands the opportunity to make tradeoffs between performance and cost during the acquisition process. This is also consistent with the use of performance incentives, which implicitly define the tradeoffs that are desired by the government.⁴

We begin our analysis with a discussion of the history of performance incentives from the standpoint of usage and policy. Particular emphasis is given to the

approach recommended by policy directives in the 1960s. The model developed to guide policy is discussed and we

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describe how efficient resource allocation can be achieved using this approach. We also briefly mention attempts made to expand this model. Using a data set of the outcomes of contracts with performance incentives during the late 1960s and early

1970s, we examine the relationship between contract outcomes and key contract characteristics. Finally, we return to the use of award fees in conjunction with performance and cost incentives.

HISTORY OF PERFORMANCE INCENTIVES IN DoD CONTRACTING

The government contracted for its first aircraft with the Wright Brothers in July 1909 at a target price of \$25,000 and a target aircraft speed of 40 miles per hour. However, for every mile per hour over the target, the contractor would receive an additional \$2,500; for every mile per hour under the target, the contractor would lose \$2,500. The minimum required speed under the contract was 36 miles per hour. The speed actually achieved by the aircraft was 42 miles per hour, so that a performance incentive reward of \$5,000 was received in addition to the target price of \$25,000.⁵

Interest in performance incentives, however, greatly increased during the

1960s. The DoD Incentive Contracting Guide, in 1962, stated⁶:

Perhaps no other DoD procurement policy offers greater potential rewards than the expanded use of performance incentives in developmental contracts. Properly conceived and applied, these incentives can do more than any other factor to encourage maximum technological progress under a single contractual effort.

As a result of this guidance, contracts including performance incentives were widely used by DoD during the 1960s and 1970s. In addition, in 1968 a special agency called the DoD Program Office for Evaluating and Structuring Multiple Incentive Contracts (POESMIC) was established. Shortly thereafter each military service instituted a policy in which all multiple incentive contracts over \$5 million be structured with the aid of POESMIC. Within two and half years of the establishment of this office over 150 multiple incentive contracts were evaluated.⁷

The policy for performance incentives developed by DoD and NASA in the 1960s, and still in effect today, is based on the assumption of hidden knowledge possessed by the single contractor. During the 1970s, attention shifted to the determination of the optimal risk-sharing relationship between the contractor and the government. It has been established that when the performance incentive function is determined in accordance with policy, and the government doesn't know the cost relationship, the contractor's share of contract costs is the parameter that

determines the optimal risk-sharing relationship between the contractor and the government. This parameter can be shown to depend on the risk tolerance levels of the government and the contractor.⁸

However, the early discussions of optimal risk sharing focused on a problem with only hidden knowledge. The contractor is assumed to maximize accounting profit on the contract with greater knowledge of the tradeoff opportunities than the government.

In the late 1970s and during the 1980s, economists explicitly drew a distinction between economic and accounting profit by introducing the disutility of effort into the contractor's objective function. Viewing the government as the principal and the contractor as the agent, one assumes that the agent's economic profit is equal to contractual profit less the implicit cost of effort.⁹

This implicit cost equals the minimum compensation required for the contractor to put forth additional "effort" and would not be part of accounting cost. In this analysis, our interpretation of this implicit cost variable is that at any time during the contract when a particular performance level is being developed, the contractor can reduce costs by working more intensively. The effort variable, however, can also be interpreted more broadly and might represent any contractor activities that are motivated by noncontractual considerations.¹⁰

The presence of asymmetric information is emphasized by economists in this analysis. The models that have been developed emphasize the role of moral hazard with hidden action, and therefore assume that the contractor knows more than

the government about certain key features of the development process. However, the government's information requirements to properly structure an incentive contract in this environment are quite demanding.

The contractor's effort level is assumed to represent a hidden action not observable by the government. To address this problem in the manner recommended by the economists, however, it is necessary for the government to know how this hidden action affects a contractor's economic profit.

In fact, during the 1960s there were extended discussions about such factors as effort and extra-contractual consider-

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ations. However, the incentive framework was deliberately narrowed because of the view that these factors could not be properly addressed with performance and cost incentives. The use of award fees based on a subjective assessment of effort was suggested as a way of coming to grips with factors that are difficult to define at the time the contract is specified.

Throughout the analysis, we focus on the use of performance incentives when there is a "sole-source" procurement relationship between the government and the contractor. Bidding issues that may arise among several contractors are either inapplicable or have already been resolved in an earlier competitive procurement.

DoD COST-EFFECTIVENESS MODEL

Because the arguments made in the 1960s remain valid today, we give particular emphasis in our discussion to the cost-effectiveness model developed during that period. Figure 1 displays the cost effectiveness model for a situation in which the total effectiveness of the weapon system is specified and the objective is to develop a performance level for each unit of equipment that achieves the specified total effectiveness level at minimum cost. In the figure, the performance level developed depends on the cost expenditure during development. Although one “expected” cost of development curve C_D is identified, there is uncertainty concerning the cost required to achieve any performance level.

Increases in the performance level, however, decrease the cost of procurement and operation, C_{PO} . For example, increases in reliability and maintainability decrease the quantity of weapons that must be procured to achieve the stated mission objective. Total (life cycle) cost equals the sum of the cost of development and the cost of procurement and operation: $T_C = C_D + C_{PO}$.

Several constant fee curves are indicated on the diagram (C_{F_1} , C_{F_2} , C_{F_3}). Notice in Figure 1 that as performance increases at a particular level of development cost, the contractor moves from C_{F_1} to C_{F_2} to C_{F_3} and the profit received by the contractor rises. As development cost increases at a particular performance level, the profit declines. Each constant fee curve, therefore, describes alternative combinations of cost and performance that

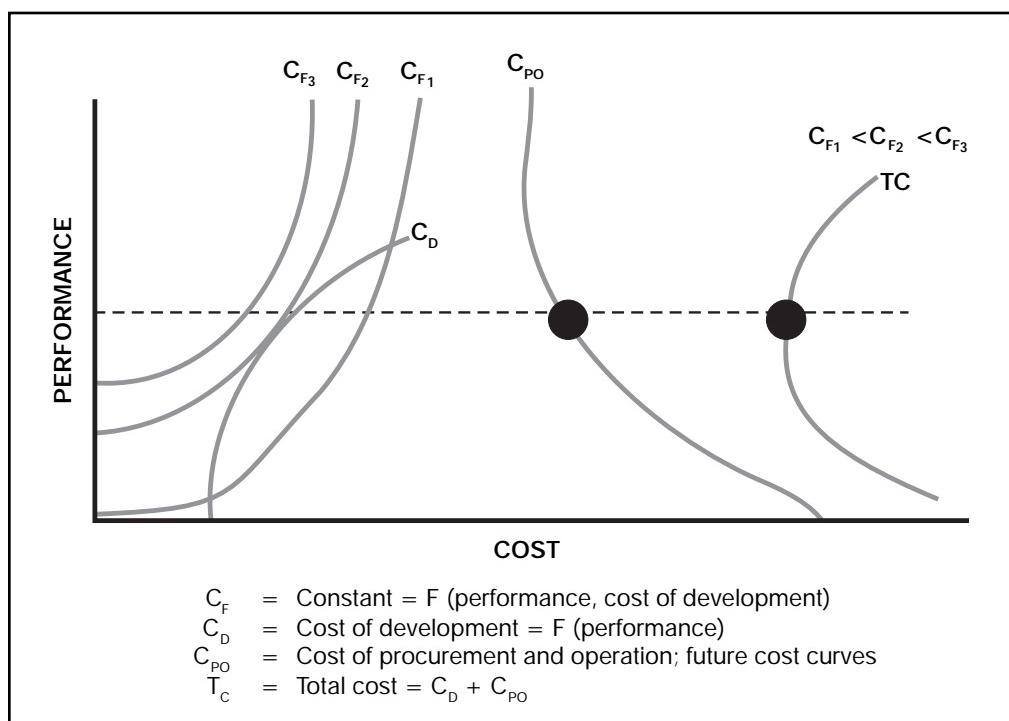


Figure 1. DoD Cost-Effectiveness Incentive Model

yield the same level of fee. Because there is a certain cost increase and performance increase that yields a constant profit level, the constant fee curves communicate to the contractor how much the government is willing to spend to increase performance.

The constant fee curves are the mirror image of the C_{PO} curve. This means that the contractor is being implicitly told that it is appropriate to spend at most an amount equal to the procurement and operations cost savings to increase performance. If the contractor maximizes accounting profit, there is no conflict between this government communication and contractor motivation.

The cost-effectiveness model assumes that there is hidden knowledge possessed by the contractor. This hidden knowledge occurs because the contractor is assumed to face a nonstochastic relationship between performance, q , and C_D at the time the tradeoff decisions are made, that is not known by the government. In this situation, the reward received for enhanced performance, Δq , should equal the contractor's share of contract costs, s , times the value to the government of enhanced performance.

The amount the government is willing to pay for enhanced performance equals ΔB . Therefore, the performance incentive function, P , should be structured so that:

$$(1) \quad \Delta P / \Delta q = s \Delta B / \Delta q$$

There is a simple logic behind this performance reward. During the development process, the maximum the government is willing to let the contractor spend for enhanced performance is the value to the government of the extra performance. The

government, therefore, is indifferent between such an expenditure and the status quo. To ensure that the contractor is also indifferent between spending, and not spending this amount, the reward for enhanced performance must just equal the contractor's lost profit from spending an amount equal to the value to the government of the additional performance. This lost profit from a cost expenditure is the contractor's share of development cost times the cost incurred.

Similarly, under this performance incentive function, if the cost of enhanced performance is less than the value to the government,

the contractor's profit would rise; if the cost is greater than the value to the government, the contractor's profit would fall.

The contractor, therefore, is motivated to make the tradeoff decisions that are in the interests of the government, even though the government does not know the cost of the performance enhancement.

“If the contractor maximizes accounting profit, there is no conflict between this government communication and contractor motivation.”

Figure 2 depicts optimal decision making by the contractor when the performance incentive function is properly specified. The downward sloping curve equals the profits from incremental performance, which from Equation 1 equals the contractor's share of the benefits to the government of the incremental performance. The upward-sloping dashed line represents the contractor's share of incremental development costs when the development costs are higher than anticipated; the upward-sloping solid line to the

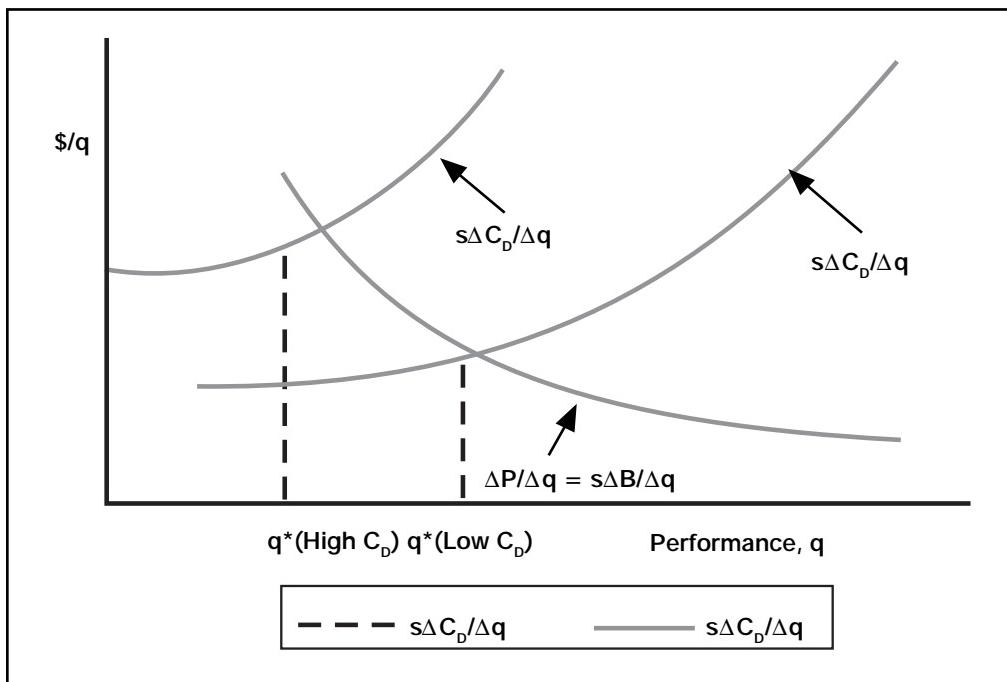


Figure 2. Contractor Decision Making with Optimal Performance Incentives

right equals the contractor's share of incremental costs when the costs are lower than anticipated.

To maximize profits on the contract, the contractor equates incremental benefits and incremental costs, $\Delta B/\Delta q = \Delta C_D/\Delta q$, as desired by the government. Therefore, performance level q^* (High C_D) is selected when development costs are high and q^* (Low C_D) when development costs are low. These are precisely the performance levels desired by the government in each development cost situation.

This approach to structuring performance incentives was taught in DoD-sponsored procurement courses as early as 1964.¹¹ In 1969, the "DoD/NASA Incentive Contracting Guide" states that

this method achieves two important objectives¹²:

first, it communicates the Government's objectives to the contractor; second, of greater significance, it establishes the contractor's profit in direct relationship to the value of combined performance in all areas.

The "DoD/NASA Incentive Contracting Guide" has never been formally superseded. In the empirical analysis we will assume that the performance incentive functions have been constructed on the basis of the guidance provided by this document.

EMPIRICAL ANALYSIS OF PERFORMANCE INCENTIVES IN DoD

Empirical analysis employs a data set developed during the years in which performance incentive contracts were used most extensively. The initial data set includes incentive contracts with performance or schedule incentives awarded from 1963 to 1972 and completed no later than 1973. There are a total of 293 contracts in the initial data set, with a total contract value of approximately \$4.3 billion. However, because the policy prescription is less ambiguous for performance incentives than schedule incentives, we focus attention on only those contracts that clearly include performance incentives. Also, during this period, contracting offices were discouraged from using performance incentives with very low sharing ratios, and we restrict the data set to those contracts with a calculated contractor's share of cost, s , between .05 and 1. After imposing these restrictions, there are 140 contracts with a total value of about \$1.73 billion remaining in the data set.¹³

In addition to the contractor's share and the value of performance, the data set also included the initial and revised target profits, the initial and revised target cost, and the contract type. Contract type refers to whether the contract is a CPIF or a fixed price incentive (FPI) contract.

Under the CPIF contract, there is both a ceiling and a floor on the profits dollars received. A FPI contract, in contrast, does not have a ceiling on profit, but there is a specified ceiling price that equals the contractor's maximum payment. At the cost level at which the ceiling price is

reached, called the point of total assumption, the contractor shares 100 percent of the costs.¹⁴

Typically FPI contracts are considered riskier than CPIF contracts. The specified contractor's share of cost is typically higher than under a CPIF contract. Also, the contractor's requirement to make delivery is more firm under a FPI contract. Under a CPIF, delivery of the contractually specified items ultimately depends on the willingness of the government to continue to allocate funds to the contract. To compensate the contractor for the higher risk associated with these factors, a higher target profit is usually awarded to compensate for the risk. The effect of contract type is outside the scope of the models developed, but is a factor whose effect needs to be accounted for in the empirical analysis.

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Typically the revised target profit, as a percent of target cost, does not vary greatly, and may hypothetically have a small effect on performance. However, it is unclear what effect large changes in target cost have on the performance level ultimately developed. We, therefore, include the percentage change in target cost calculated, relative to the original negotiated level, in the hypothesized model. This is another variable not included in the cost-effectiveness model that must be accounted for in the empirical analysis.

The following variables are therefore included in the empirical analysis:

- Y_i = Performance level developed relative to target (measured as value to government)
- s_i = Contractor's calculated share of cost
- π_{Ti} = Adjusted target profit
- C_{Ti} = Adjusted target cost
- PCT_i = Percentage change in target cost
- D_i = contract type (if FPI, $D_i = 1$; if CPIF, $D_i = 0$).

We need to emphasize that the performance incentive function is assumed to be structured so that Equation 1 is satisfied. As a result, knowing the contractor's share of cost and the profit received for performance permits calculation of Y_i . When Y_i is regressed on the remaining variables, the following estimated equation is obtained (t statistics in parenthesis):

(2)

$$Y_i = 660.70 - 124.93s_i + 1.89\pi_{Ti} - 0.06C_{Ti} - 3.01PCT_i - 1724.32D_i$$

(-0.41) (3.46) (-1.57) (-0.62) (-2.71)

$N = 140, R^2 = .29$

The contractor's share of costs is not statistically significant. This is consistent with the cost-effectiveness model. Higher target profit, however, does explain significant variation in Y_i , while target cost is only marginally negatively significant. The percentage change in target cost is statistically insignificant, and the contract type is significant. The coefficient of D_i indicates that, other things equal, FPI contracts tend to be associated with lower performance.

When the variable PCT_i is deleted from the regression model and the regression

equation is reestimated, one obtains:

(3)

$$Y_i = 576.99 - 119.20s_i + 1.91\pi_{Ti} - 0.07C_{Ti} - 1703.01D_i$$

(-0.39) (3.50) (-1.62) (-2.68)

$N = 140, R^2 = .29$

For the variables retained in Equation 3, the coefficients and t-statistics are quite similar to those obtained in Equation 2.

While the DoD cost-effectiveness model predicts that the performance level selected does not depend on s_i , π_{Ti} , or C_{Ti} , both π_{Ti} , or C_{Ti} are significant in the empirical analysis. The theory, however, is silent on the effect of contract type on performance outcome. The model fails to address the proper structuring of a contract at this level of detail. Clearly, further analysis is needed to understand why π_{Ti} , C_{Ti} , and D_i are statistically significant in the empirical analysis.

AWARD FEES AND PERFORMANCE INCENTIVES WITH OBSERVABLE EFFORT

A full discussion of the models developed by economists to address asymmetric information is beyond the scope of this paper. Interestingly, even though the theoretical analysis arises from the asymmetric informational relationship that exists between the government and the contractor, there are demanding informational requirements to implement the theoretical models. In his discussion of a simple procurement problem with effort unobservable by the government, William Rogerson notes:¹⁵

For normative purposes, the problem...is that the precise na-

ture of the optimal contract is highly dependent on features of the contracting environment that the government may be unsure about. For positive purposes, the problem is that the theory does not generate testable predictions. Therefore...the major value of this model to date has been to clarify the underlying incentive issues rather than to explain specific contracting phenomena.

This suggests that the information needed to implement many of the ideas from the theoretical literature is not available. Although we will not provide a detailed summary of the theoretical developments, suffice it to say here that an important distinction is made between accounting profit, π_A , and economic profit, π . For example, it has been assumed that economic profit equals accounting profit minus the unobservable implicit cost of contractor effort:¹⁶

$$(4) \quad \pi = \pi_A - h(e).$$

The function, $h(e)$, measures the implicit dollar cost of this effort to the contractor, that is, the amount the contractor must be compensated to attain various effort levels. In this analysis, contractor effort is assumed to be directed at development cost reduction. As discussed above, however, it is also possible to interpret the effort variable as representing the extra-contractual influences on government contracting. As long as there are such extra-contractual influences, it is unlikely that the contractor will only be motivated by the accounting profit received on the development contract in question. The

assumption, therefore, that accounting profit on the contract in question and economic profit differ is probably valid.

However, government personnel in the program office and those who actually work at the contractor's plant actually possess a great deal of information about both the contractor's effort and the disutility of this effort. There is probably an observational horizon level below which the contractor behavior is not observable to the government.

" ...government personnel in the program office and those who actually work at the contractor's plant actually possess a great deal of information about both the contractor's effort and the disutility of this effort."

For example, the government may be unable to observe many of the micro and micro-micro tradeoffs made among performance characteristics and between performance and cost.

Above this horizon, however, the government may be able to assess the contractually relevant characteristics of contractor behavior to include various dimensions of the contractor's effort. We, therefore, analyze a situation in which detailed information related to tradeoffs is unobservable, but the disutility of effort is known to the government by the completion of the contract when accounting cost and performance level are known. Over the course of the contract, the government is assumed to gather sufficient information about the contractor's behavior that the compensation required to bring forth additional effort levels is known. And the contractor

knows that the government possesses this information.

Given this information structure, we consider the use of an award fee, A , in which profit depends on the government's subjective assessment of the contractor's relevant effort. The following analysis, therefore, should be viewed as a theoreti-

"The contractor should receive an incremental profit for objectively measurable performance equal to the cost share times the value of enhanced performance."

cal construct to understand the CPAF/IF contract used on the F/A-18E/F. The Appendix contains a detailed discussion of a model that accounts for the information

likely to be possessed by the government. However, the basic logic of the appropriate incentive arrangement is straightforward.

With respect to the performance incentive component of the contract, Equation 1 continues to apply. The contractor should receive an incremental profit for objectively measurable performance equal to the cost share multiplied by the value of enhanced performance.

In this model, the contractor's effort is observable by the completion of the contract, and we assume that when the contractor increases the effort level, Δe , to develop a performance level, there will be a reduction in cost, ΔC . Or, what is really the opposite of the same coin, holding development cost constant increases in effort yield an increase in the performance level developed, Δq .¹⁷

Viewing effort from the standpoint of cost reduction, the benefit to the government resulting from the increase in effort

equals $-\Delta C$. But the implicit cost borne by the contractor, Δh , is a social cost to the government. As a result, the government desires that the marginal benefits of additional effort equal the marginal cost:

$$(5) \quad -\Delta C/\Delta e = \Delta h/\Delta e.$$

The contractor is given an award fee, A , that depends on observable effort. When effort is increased by Δe , profits from the cost incentive increase by $-s\Delta C$, but there is also an implicit effort cost, Δh , borne by the contractor. The contractor chooses the optimal effort level to obtain the associated change in the award fee, ΔA , so that when this incremental gain is added to the incremental benefit from cost reduction, the sum just balances incremental effort cost. The following condition, therefore, holds for the contractor:

$$(6) \quad \Delta A/\Delta e - s\Delta C/\Delta e = \Delta h/\Delta e,$$

where $\Delta C/\Delta e$ is negative.

When the objective of the government (Equation 5) is combined with the objective of the contractor (Equation 6), the award function, A , should be specified (at the completion of the contract) so that:

$$(7) \quad \Delta A/\Delta e = (1 - s)\Delta h/\Delta e.$$

Incremental award fee should equal the government's share of the incremental cost of effort. The reason why the incremental cost of effort, $\Delta h/\Delta e$, is offset by $s\Delta h/\Delta e$ can be seen by examining Equation 6. The contractor is compensated for the reduction in cost obtained from incremental effort through the cost incentive. The remaining compensation needed

for the contractor to select the appropriate effort level is determined by Equation 7.

It has been shown, therefore, that an award fee can be used to augment a contract that also includes cost sharing and performance incentives to aid in the achievement of the objectives of the government.

FINAL OBSERVATIONS

The cost-effectiveness model of the 1960s has an appealing simplicity. Performance and cost incentives aid the efficient allocation of resources even though the contractor knows more about the tradeoffs between performance and cost than the government.

The observable effort model, which also includes an award fee, combines the simplicity of the cost-effectiveness model with the type of knowledge the government is likely to possess at the completion of the contract. It may provide a way of conceptualizing the use of award fees with multiple incentive contracts.

Federal profit policy emphasizes the need for an equitable profit to be earned by the contractor and for risks to be appropriately shared.¹⁸ Performance incentives reward the contractor for developing a system that achieves the objectives of the government. In addition, as these performance incentives are employed with cost incentives in either a CPIF or an FPI contract, appropriate risk sharing can be obtained. Effectively, the government and the contractor share in the net benefits obtained from the system developed.

The addition of an award fee provision further aids the achievement of the government's objectives by awarding the contractor for efforts that can't be defined at the time the contract is structured. They also help guide the contractor toward contractual rather than extra-contractual activities. Further analysis of the combined use of performance incentives and award fees is clearly merited. The F/A-18E/F contract provides the type of case material needed to begin this analysis.

APPENDIX

We assume that during development that economic cost equals accounting cost, C , less the implicit cost of effort, $h(e)$. To achieve allocative efficiency, the following problem must be solved:

$$(A1) \text{ Maximize } W(q_r) + B(q - q_r) - C(q, e, \theta) - h(e), q, e$$

The function W represents the gross benefits received by the government from target performance level q_r . The benefit function, $B(q - q_r)$ represents the willingness of the government to pay for the difference between actual performance q and target performance. The contractor's accounting cost function, C , depends on actual performance developed, effort, and the variable, θ , which represents information known to the contractor, but not the government at the time the tradeoff decisions are made. Problem A1 has the following first-order condition, where the subscript of a function indicates the variable with which the derivative of the function is being taken:

$$(A2) \quad B_q = C_q$$

$$(A3) \quad -C_e = h_e$$

Equations A2 and A3 indicate that the marginal benefit of performance equals marginal cost, and the benefit from a reduction in accounting cost resulting from an additional unit of effort just equals the marginal disutility of effort.

We now add an "award fee," A , which awards the contractor at the completion of the contract for "efforts" undertaken. At the time the contract is specified, this function cannot be objectively defined. However, during the course of the contract, the government is assumed to develop a strong sense of the nature of this function. The contractor is assumed to understand how the government formulates the award fee function, and in maximizing economic profit, π , solves the following problem:

$$(A4)$$

$$\text{Maximize } \pi = \pi_T + P(q - q_r) - s[C(q, e, \theta) - C_T] + A(e) - h(e), q, e$$

where s equals the contractor's share of costs. Solving this problem yields:

$$(A5) \quad P_q = sC_q$$

$$(A6) \quad A_e - sC_e = h_e.$$

If the government sets $P(q - q_r) = sB(q - q_r)$ as required by Equation 5, and sets $A = (1 - s)h$, as required by Equations A3 and A6, the optimal performance level q and the optimal level of effort e are achieved.¹⁹ The efficiency conditions A2 and A3 are thereby satisfied. As a result, under the assumption that the government can observe the contractor's effort by the completion of the contract, a contractual outcome with very desirable properties is achieved.

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ENDNOTES

1. For example, see Leitzel and Tirole (1993), and Bower and Dertouzos (1994).
2. Shields (1996). CPIF/AF contracts are also employed on the Joint Standoff Weapon (JSOW) and AIM9X missile EMD contracts.
3. Kaminski (1996). For additional discussion of performance specifications, see Department of Defense (1995). With respect to the ORD, threshold is minimum required performance and objective is a more highly desired performance level.
4. See Rush (1997).
5. Cook, et al.(1967), p. 1.
6. Department of Defense (1962), p.30. Sherer (1964), p. 172.
7. Jones (1970).
8. The risk sharing problem as it relates to performance incentives was analyzed by Hildebrandt and Tyson (1979).
9. One of the clearest summaries of the modern approach to incentive contracts is contained in Kreps (1990, pp. 577–616). Extensive references of the earlier literature are provided.
10. Department of Defense and NASA (1969, pp.249–254), includes company growth, prestige, opportunity for follow-on business, and utilization of available skills and open capacity as “extra-contractual influences on government contracting.” Typically, however, the DoD and NASA *Incentive Contracting Guide* implicitly assumes that the contractor is primarily motivated toward the accounting profit on the particular contract.
11. Case materials using this technique were developed by Harbridge House, Inc., in 1964. A formalization of the technique is contained in Cook et al. (1966, pp. 91-95).
12. Department of Defense and NASA (1969, p. 107). Underlining included in document.
13. The data was obtained from the Office of the Assistant Secretary of Defense, Comptroller, in December 1974.
14. For a discussion of contract types see Department of Defense and NASA (1969, pp. 3–6).
15. Rogerson (1995, p. 324).
16. See Kreps (1990).

17. If the development cost relation is of the form $C = C(q,e)$, it can also be written as a performance development relation, $q = q(C,e)$. If an uncertainty variable is introduced into the cost relationship, one can view cost and technological uncertainty as the same phenomenon.
18. The role of risk allocation in government profit policy is discussed in Cibinic and Nash (1995, Chapter 3).
19. Note that π_T can be set to achieve the appropriate target level given the expected cost, performance, and effort levels.

